

The influence of urban structure on commuting: an analysis for the main metropolitan systems in Spain

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Abstract

It is widely recognised that urban mobility is responsible for the generation of an important proportion greenhouse gasses produced by households, at the time that it has important social and economic implications for urban sustainability. Nonetheless, in the literature few attention has been placed on the relationship between urban structure and commuting. In this paper, using travel-to-work data for the main seven metropolitan systems in Spain we investigate both the impact of polycentric urban development on labour mobility and other urban factors influencing excess commuting. In doing so, a synthetic indicator of travelled distance is constructed and correlated to polynucleation and polycentricity indexes. Also an econometric family of models is built to regress excess commuting, after controlling for urban structure, over infrastructure and transport services, labour market structure, housing amenities, commuters' income level, orographic complexity. Results suggest that effectively there is an inverse relationship between the number and size of subcentres in terms of employment (polynucleation) and the distance travelled by commuters, nevertheless, such relationship is weaker with the strength of functional linkage between subcentres and their hinterland (polycentricity), which in turns suggest the presence of other factors influencing commuting. According to regression analyses, commuting is exacerbated in areas well served by private and high capacity public transport, also in zones where employment dominates over housing, especially if jobs are basically oriented to manufacturing. On the contrary, the diversification of housing typologies reduces labour mobility. In sum, urban structure and other planning-modifiable urban attributes seem to have an endogenous potential to mitigate commuting in metropolitan systems, and consequently contribute to reduce climate change.

Keywords

Polycentrism, urban mobility, travel to work journeys

1. Introduction

From a social point of view separating employment and residence results into prejudicial consequences for social groups of limited mobility; from an economical point of view distancing firms means losing the opportunity to take advantage of external economies and from an environmental point of view scattering results in excessive land consumption and environmental costly transport systems. In Spain this latter topic has become especially relevant in the course of the last 15 years, a period in which the real estate sector has produced several times the actual demand for housing, most of the times following a high land consumption scheme. Such a concern has clearly trespassed the national jurisdiction as it is reflected in the Auken Report for European Parliament concerning the impact of extensive urbanisation and environmental menaces particularly in coastal zones (Auken, 2009).

Politicians, especially in Europe, have seen polycentric development as an alternative model to dispersion allegedly leading to cohesion, competitiveness and sustainability (Meijers, 2008); although, the empirical basis of such benefits is still weak and in some cases is contradictory (Boix & Trullén, 2012). In such a way, it has been said that polycentricity has much of normative rather than analytical (Green, 2007). Our main goal is to explore to what extent subcentres do have an impact on house-job travelled distances, and thus shed light on the environmental sustainability of policentricity in the regional context of the metropolises analysed.

It is widely recognised that urban mobility is responsible for the generation of an important proportion greenhouse gasses produced by households, at the same time it has important social and economic implications for urban sustainability. Nonetheless, in the literature few attention has been placed on the relationship between urban structure and commuting. In this paper, using travel-to-work data for the main seven metropolitan systems in Spain we investigate both the impact of polycentric urban development on labour mobility and other urban factors influencing excess commuting.

The remaining of the paper is structured as follows: 1) a brief literature review on the relationship between urban structure and travel to work is presented, 2) after the case study, methodology and data used in the paper is introduced, 3) results are discussed in the following part and 4) a general review of the main findings is summarized in the conclusive epigraph.

2. The influence of urban form on commuting in the literature?

The relationship between land uses and transport is a constant in most of the theoretical urban models such as those proposed by urban economics, where it appears to be a trade-off between transport cost and land rent that at the same time influence the location of households (Mills, 1972). Nonetheless, such models have been criticised in the paradigm of sustainability where

the study focus has been displaced from transport to mobility. According to this new theoretical framework travel decisions depend upon a number of factors beyond the availability of infrastructures and transport services (Miralles, 2002). Such a novel approach considers that the influence of job location on the residential choice has declined as other factors have emerged such as the deregulation of labour markets, the demographic transition (i.e. changes in the household formation, the increment of life expectancy and the number of employed people inside households), the importance of leisure aligned to the increment of income and postindustrialization. In that process the emergence of ICT has also produced the redistribution of productive functions across the city (Champion, 2001; Flamm y Kaufmann, 2006). On the other hand, the revolution of transport systems empowered by the revolution of informational devices applied to transport and mobility have eased the space friction space and facilitated long distance commuting. All together has negatively influenced the linkage of the home-job relationship and of course the mobility connexion between the place of residence and the job place.

The aforementioned issues do not cancel the relationship between urban form and mobility, but reveals the existence of other factors that might have an influence on commuting. The existing research depicts two approaches to the study of urban form and mobility as described below.

The co-location of employment and population within the zones

From an intra-zone perspective there is an open discussion on the influence that produces the balance between employment and housing over commuting patterns. A given zone is considered in balance when its working population can get a job located within a reasonable distance. Therefore, the imbalance occurs when there is a significant difference between the number of working population and job places producing as a result commuting with destination and/or origin in other zone (Cervero, 1989; Giuliano & Small, 1993). From that perspective, a number of studies at the end of the eighties explored the relationship between the job/housing ratio, and the exclusive zoning, and the important increase in commuting and congestion. Such studies did find a weak and no-linear relationship between the land use allocation (i.e. job/housing ratio) and the distance of commuting (Peng, 1997): only the highly unbalanced ratios appeared to have an influence on commuting. On the contrary, this research field revealed other factors influencing the residential choice apart from the proximity to the working places. Aspects such as the quality of the environment, the perceived security (Wachs & Taylor, 1993; Giuliano & Small, 1993) and the existence of services and leisure facilities (Aguilera & Mingnot, 2004) proved to have a role in the residential election. Perhaps, behind the weakness of the above-mentioned relationship resides the oversimplification of the co-location hypothesis. In cities where land markets arbitrate the residential allocation, the income level, necessities and affinities of households need to be taken into consideration (Giuliano & Small, 1991). Therefore, the quantitative balance between the number of dwellings and workings places is insufficient to produce a containment of commuting, it is necessary a qualitative matching between the housing market and the possibilities and aspirations of householders. Other evident problem in this first approach is the indexation of the number of working places to the number of dwellings,

when clearly in contemporary demographic structures there is not a unitary correspondence between the number of households and working population.

The spatial distribution of employment and population across the zones

The idea that the spatial structure of cities does influence the patterns of commuting is not new: “Policentricity is identified as an efficient urban form since it reduces commuting times, and thus transport costs. Under that perspective, the monocentric city becomes inefficient since urban growth induce congestion in central zones” (Clark & Kuijpers-Linde, 1997; pp. 3-4). Such polycentric framework implies that economic activities do agglomerate in subcentres across the space reducing the distance travelled by working population living both in the subcentres and their hinterland. This hypothesis is also derived from theoretical models of polycentric growth, which support the idea that multicentre cities emerge when transport costs and congestion are important (Fujita & Ogawa, 1982). The work of McMillen & Smith (2003) for 62 metropolitan areas in US has empirically proved the relationship between the number of subcentres and both the size of the urban area and transport costs. Does such polycentric structure directly imply the reduction of commuting? Cervero & Wu (1997) find in San Francisco that commuting in central areas is 30% longer (in distance) than in subcentres (e.g. Silicon Valley), which in turns suggest that polycentrism implies less commuting. Aguilera (2005) has arrived to the same conclusion for the three largest cities in France, where the existence of subcentres allows that resident population living around them has shorter commuting, but not as short as it is directly derived from theory.

The above-mentioned conclusion does not hold when the data is analysed from a diachronic perspective. Cervero & Wu (1998) fail to demonstrate that the concentrated decentralization of employment, which reinforce polycentrism, is positively associated with the reduction of travelled distance. Such a conclusion converges with the work of Baccaini (1997) for Paris where employment decentralisation is parallel to residence decentralization. As consequence the possible benefits from employment polynucleation are eclipsed by the simultaneous change of residence location. Gordon *et al.* (1986) find contradictory evidence for Los Angeles (1970-180), according to their study in a parallel decentralization process where population sprawls across the metropolitan area and employment clusters among secondary centres commuting is reduced due the increase of short travel distance in peripheral zones. Perhaps such divergence can be solved using commuting time instead of travel distances, since peripheral areas have less congestion and higher travel speeds than central zones. Using this second approach, Sultana (2000) finds that in Atlanta dispersed employment nuclei do reduce travel distance in relation to those centrally located, as well, the author reports a positive correlation between the size of the centre in employment terms and the travelled time. Nonetheless as the author notes Atlanta suffers from congestion in central areas, thus short travel times in subcentres may imply larger travel distances using private cars as it has already been proved in San Francisco by Cervero & Wu (1997).

The study carried out by Aguilera (2005) is unique since it uses both of the approaches to analyse whether the polycentric urban structure induces along the time a job/housing co-location. Her

findings for Paris, Lyon and Marseille in the period 1990-2000, suggest that from a synchronic perspective polycentrism shortens commuting distances; nonetheless from a diachronic perspective its influence in governing commuting patterns vanishes. According to her study, as the time goes, subcentres reduce both the self-containment and self-sufficiency, it is to say, their capacity to retain working population and satisfy labour demand of localised firms. In turn, this process produces larger commuting distances both from the perspective of in-commuters and out-commuters. Thus the polycentric structure from a dynamic perspective fails to reinforce both the job/housing co-location and the travelled distance. García-López (2010) arrives to a similar conclusion in his study for the metropolitan area of Barcelona. In such a city the historical capacity of the centre and subcentres to govern the overall population density collapses in favour of the increasing influence of transport infrastructures for the studied period.

The contradictory evidence previously reported may originate from:

- 1) The oversimplification of the relationship of housing and employment. Since it is evident the enormous diversity existing both in employment qualifications and housing demand/offer. Thus it is expectable that the residential and labour market only interacts (complements each other) when there is a correspondence both in labour skills and the necessities and possibilities inside the housing market. In such respect, Laan (1998) and Schwanen *et al.* (2001) agree that polycentrism only reduce travel distances in the case that suburban labour market (structured by subcentres) is independent from that located in the centre of the city. If such a differentiation fails to exist, thus policentricity may foster travelled distances due the cross-centres commuting.
- 2) The fact that previous studies fails to separate mature subcentres from emergent ones. Especially in Europe policentricity is associated to the functional merging of former independent centres and their hinterland. Such historic centralities have a diversified labour and residential market that allows to match different skills and housing necessities/affordability, fostering in that way self-containment of population. On the contrary, emergent subcentres are usually associated to mono-functional land uses with poor facilities and services fostering in that way urban mobility.

In this paper we try to solve both of the aforementioned issues as it is explained in the next section.

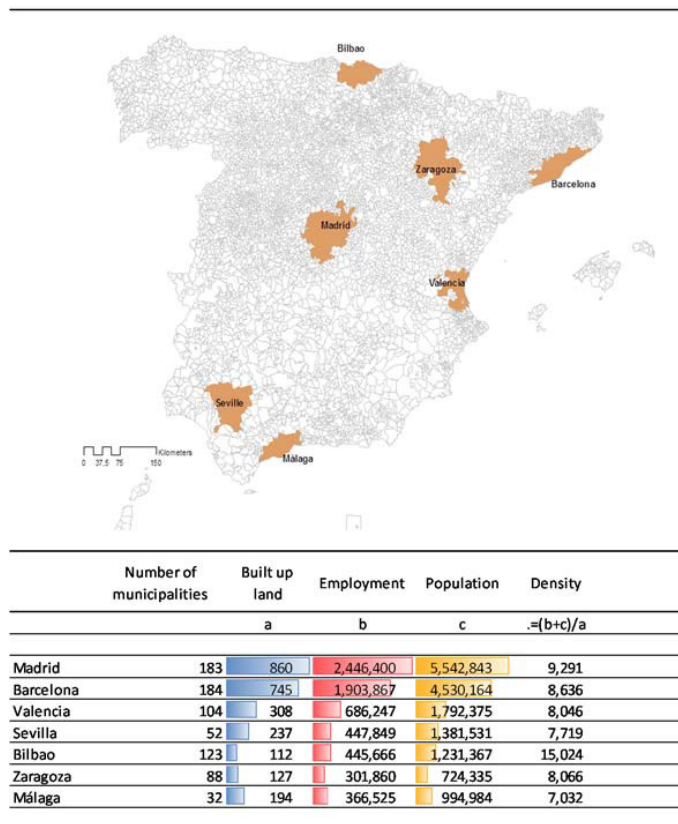
3. Case study, data and methodology

3.1 Case studies

In this paper we study the impact of polycentrism on labour commuting in the seven largest cities in Spain: Madrid, Barcelona, Valencia, Bilbao, Seville, Saragossa and Malaga as delimited by Marmolejo *et al.* (2012). Using travel to work data such authors, using the so called, interaction value, also identify the structure of metropolitan cities, it is to say, the delimitation of main centre and subcentres, and the area structure by them named subsystem. Figure 1 depicts the main figures of the studied cities and figure 2 the structural form. Barcelona, Valencia

and Bilbao stand as the areas with the highest number of subcentres, that conjointly concentrate a significant share of employment (ranging from 20% in Valencia to Barcelona with 22%); at the same time those metropolitan areas do concentrate the lowest share of employment in their expanded-CBD¹ (ranging from 47% in Valencia to 56% in Bilbao). Exactly in the inverse position are Madrid, Seville and Saragossa, which stand as the most monocentric and less polycentric metropolises in Spain. Malaga is an outlier, because having only 4 subcentres they have an important share of employment (23%), and at the same time its expanded-CBD is not to big as in the case of monocentric metropolises.

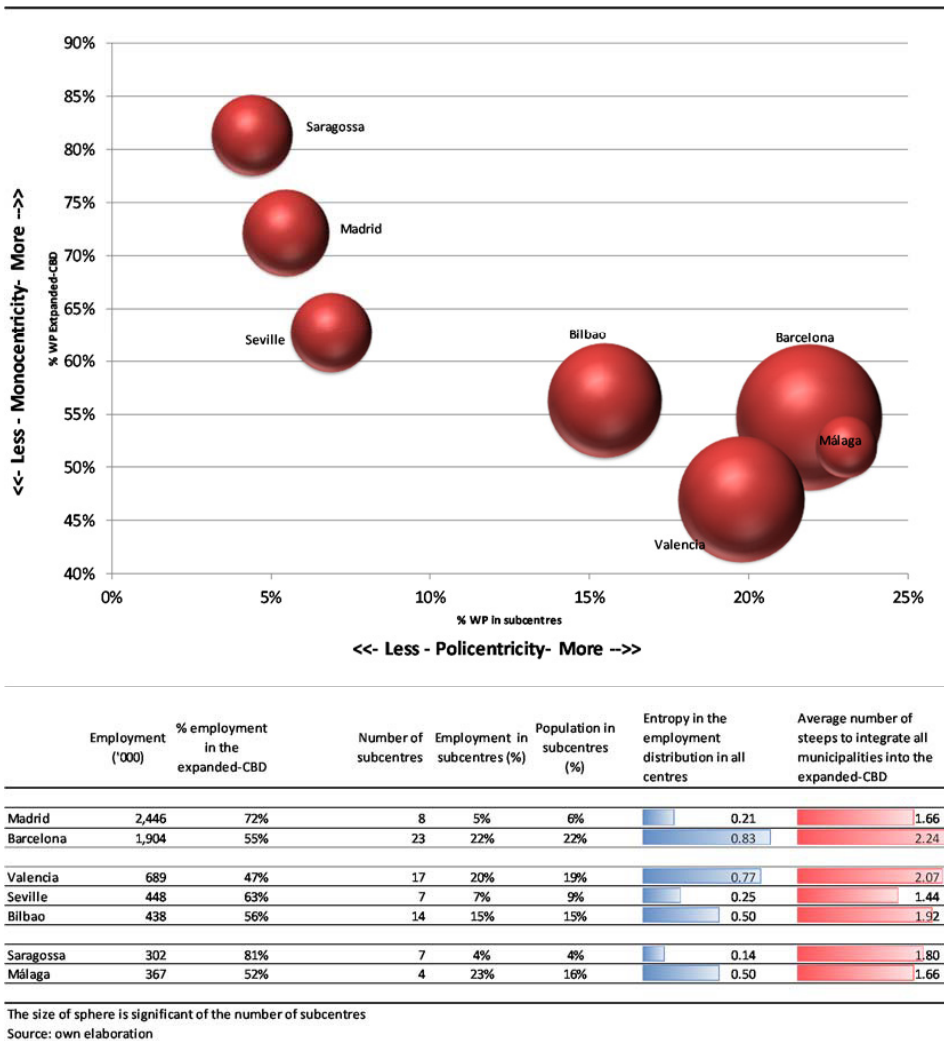
Figure 1 Main figures of biggest metropolitan areas in Spain



Source: Corine Land Cover & National Census 2001 (ICN, INE)

¹ We compute as extended-CBD those municipalities that: 1) are part of the urban continuous of the main municipality –i.e. their urbanized patches are closer than 200 m- and 2) are inside of the functional subsystem of CBD as detailed above in the main text.

Figure 2 Structure of the metropolitan areas in Spain



3.2 Data

We primary use data coming from the National Census 2001 (the last reliable that is available) at municipal level (the smallest unit for travel to work data at destination). Departing from such a source we use:

- 1) Travel to work data used to delimit metropolitan areas and identify subcentres as well as characterize commuting patterns
- 2) Characterize the labour market in terms of industrial classification of sectors, diversity of the economic activities, as well as type of occupation
- 3) Characterize the income level, departing from the occupation of working population
- 4) Characterize the housing market departing from the size and quality of houses

Also we use Corine Land Cover to analyse land use patterns. Corine (Coordination of Information on the Environment) Land Cover project for the year 2000, is leaded by the European Environment Agency, and it uses satellite imagery from LandSat and SPOT to make the photo interpretation of the use of land inside the EU. With such information we calculate:

- 1) The consumed land per capita at municipal level
- 2) The fragmentation of urban fabrics², it is to say the level of discontinuity of the urban tissue

Finally using the Digital Terrain Model we obtain the orography of urban areas. Distances between municipalities are computed using TeleATLAS cartography.

All the information is managed and analysed using ArcGIS (for land use and digital terrain model), TransCAD for travel to work modelling and SPSS for the statistical analysis.

3.3 Methodology

In order to prove the relation between polycentrism and commuting patterns we construct the excess commuting indicator, departing from the optimal commuting index of White (1988), that minimizes:

$$CT = \sum_i \sum_j (C_{ij} X_{ij})$$

Where

C_{ij} is the cost of commuting (distance)

X_{ij} is the number of workers that Works in zone i and travel to zone j

Put in simple, such excess commuting index compares the optimal commuting (all the workers commute to the nearest available job place) to the actual commuting. The higher the indicator,

² The fragmentation has been computed using the Shannon entropy formula:

$$H_i = -1 * \sum_{x=1}^n P x_i * \ln(P x_i)$$

In this case P is the probability to find urbanized land in a given x spot in a x municipality. In a x municipality are as many spots as urban patches are. If two patches are separated by a gap inferior to 200m it is considered that form part of the same patch. This later criteria allows for consider the interruptions caused by rivers and other lineal infrastructures (e.g. high voltage electric lines).

the higher the unnecessary commuting. The calculus of optimal commuting has been performed in TransCAD³ software using the built-in optimization model.

Finally, we regress excess commuting indicator over indicators of urban form: housing balance, distance to CBD and subcentre, transport facilities, income level, employment mismatching (the level of coherence between the employment and work force qualification), employment diversity.

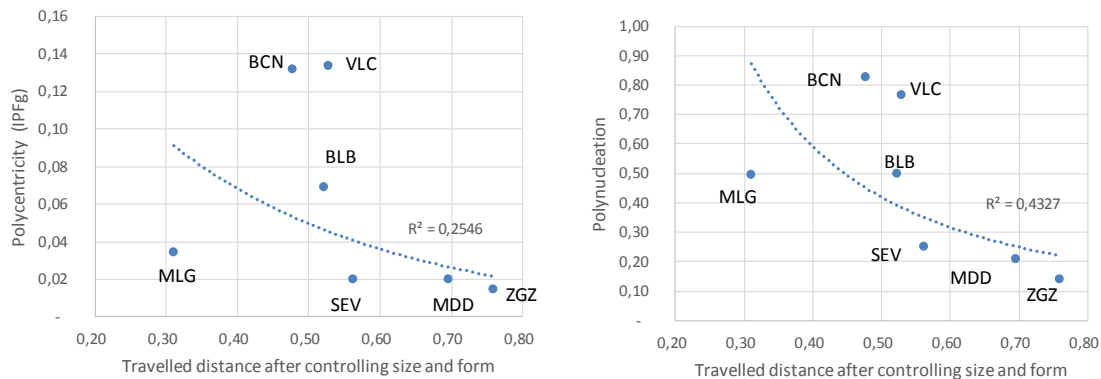
4. Results

The following figure depicts the correlation between commuting and urban structure. As shown there is an inverse correlation between polycentrism and the travelled distance by commuters. Commuting is represented as the ratio of the total travel distance in a given metropolitan area to the total travel distance if such area were completely monocentric (i.e. all employment were to be concentrated in the CBD). The higher the ratio, the more monocentric is the area. This approach allows for controlling the difference of size and morphology of the different metropolitan areas studied. Polycentrism is represented by 2 alternative indicators:

- Polynucleation is built as an indicator of the evenness of employment distribution across subcentres inside a metropolitan area. The higher is the polynucleation, the higher the uniformity of distribution of jobs in the subcentres (See Marmolejo *et al.*, 2015)
- Polycentricity is built upon Green (2007) that measures the functional linkage (i.e. commuting flows) between subcentres. The higher is the polycentricity, the higher the linkage in the subcentre network.

³ The sources of information are two, in terms of demographics and mobility from residence to work in 2001 are extracted from the National Statistics Institute (INE) of Population and Housing provided by the Census and in terms of infrastructure the road network of Tele Atlas year 2001. With all of these three matrices of travel flows have been developed with TransCAD 5.0 software. In this software has been worked with three covers, one with municipal information, another with the network calculated with Tele Atlas and other last, that of centroids of each municipality, which represents the centre of gravity of each municipality.

With data and cover three matrices of travel flows are calculated. First, the current commuting between each centroid of each municipality. The second, the distance matrix, in kilometres, where distances that cross population of a municipality of residence to another to work are shown. And finally the third matrix, the optimal commuting matrix, that means, repositions in simulated way so people have to travel the shortest distance (minimal cost) to get from his home to his work.

Figure 3 Polycentrism and travelled distance (home-work)

Source: own elaboration

The excess commuting indicator controls for the distribution of employment and population, but not for the remaining of urban factors that may influence commuting. The following table contains the results of a family of lineal regression models built to explore the relationship between excess commuting and a number of urban features.

The first model “Transport” is able to explain only 3% of the variance of excess commuting, according to such a model the higher is the presence of railway stations (most of them rendering a suburban-radial train service), the higher the excess commuting, such a finding suggest that working population living in well-connected areas serviced by high capacity transport network do travel more that those living in poorly connected areas. The second model “urban form” is able to explain 19% of the excess commuting, which is relevant to the interest of this research since its explanatory capacity is the highest among individual models. According to such a model, the higher is the presence of manufacturing activity the higher is the excess commuting; such a finding is relevant, since during the last four decades in Spain, as well in other parts of the world, most of the new and decentralising economic activity has been accommodated in industrial parks located in suburban places. The positive sign of the coefficient suggest that manufacturing premises does not encourage the self-contentment of site’s working population, on the contrary those municipalities depicting a high level of such activities denote the highest commuting patterns, and behind this issue is the fact that manufacturing locations are well serviced by motorways connecting them with the remaining of the metropolitan system. The second coefficient is the dwelling diversity, such an indicator represents the diversity of housing in terms of size (as a proxy of housing typologies), the negative relationship with excess commuting suggest that well developed residential areas (with a diverse offer of dwellings matching different income levels) do have a higher self-containment of commuters, since they are able to find the house they can afford or that fulfils their residential expectations. The mismatching

CNO coefficient is significant of the non-correspondence between the working population and the employment in a given site in occupational terms. The higher this coefficient is, the bigger the mismatch between the offer and demand of jobs in qualification terms is. The positive correlation of this index and excess commuting ratifies that very specialized job places, which labour force do not match the qualification required by firms do produce higher commuting patterns that balanced zones. Finally, the job ratio (the number of job places to working population) confirms that very economic specialized zones (e.g. manufacturing parks); paradoxically do not contribute to the reduction of commuting, the reversed sign of the square of job ratio suggest and exponential function in the relation with excess commuting.

The income model is constructed over the principal component analysis that summarizes the socio-professional structure of working population. In such a factorial analysis high income is assumed to be linked to managerial and professional working population, medium income is related to workers employed in the personal service sectors, and medium-low profiles includes also the medium qualified manufacturing working population. As suggested by the model there is not a linear relationship with excess commuting and income as theory suggest, high qualified workers depict a negative relationship with excess commuting which indicates that these professional profiles tend to live near their job locations, exactly the same is true for medium-low profiles. The operational principia are the same in both cases, since their income make wealthiest workers live in expensive locations near office based jobs, at the time that blue-collar-workers only can afford housing in the poorest residential areas that are quite often located next to manufacturing locations. On the contrary, medium income population seems to have longer commuting patterns, since their employment oriented to people services is more sprawled across city.

In the integrated model all the precedent models are integrated in a unique one. Some of the variables are introduced and other eliminated. For example in the transport infrastructure dimension the motorway service (expressed as the number of accesses by 10.000 inhabitants) is introduced with the expected positive sign, in the urban form dimension distance to CBD is introduced with a positive sign which suggest that peripheral municipalities show higher excess commuting as expected, other control variables include the orographic complexity with a positive sign that reveals that hilly territories increase the commuting patterns and dummies controlling the cities.

As observed the distance to subcentre does not have any influence on excess commuting, as well the dummy representing the subcentre is not introduced in any model. This finding is not surprising since, as it has been previously indicated, the excess commuting indicator controls, by definition, urban form, it is to say the spatial distribution of both employment and population.

Table 1 Excess commuting models

		MOD1		MOD2		MOD3		MOD4	
		Transport		Urban form		Income		Integrated	
	R	0,17		0,44		0,24		0,52	
	Sq R	3,0%		19,2%		5,9%		27,3%	
	Sq R adjusted	2,9%		18,7%		5,5%		26,2%	
	Error típ.	0,94		0,86		0,93		0,82	
		B	t	B	t	B	t	B	t
Dim	Constant	1,06	29,82	1,90	5,07	1,10	31,85	0,86	2,23
T	Stations/10.000 inha	0,03	4,74						
	Motorway acc/10.000 inhab							0,00	3,49
UF	% manufacturing			1,88	8,95			1,04	4,65
	Dwelling diversity			- 0,90	- 4,77			- 0,49	- 2,51
	Mismatching C N O			0,57	3,44				
	Job ratio			- 0,02	- 4,14				
	Job ratio*2			0,26	3,62			- 0,03	- 5,80
	LTL/Viv tot							0,51	5,66
	Distance to CBD							0,01	3,23
TM	Orographic complexity							0,14	2,34
INC	Medium low					- ,169	-4,853		
	Medium					,119	3,380		
	High					- ,112	-3,239		
I	Bilbao							0,41	3,83
	Valencia							0,59	5,86
	Málaga							- 0,47	- 2,86
	Zaragoza							0,34	3,32

T= Transport, UF= Urban Form, TM= Territorial matrix, INC=income, I=dummy for diferent cities

5. Discussion and policy implications

Since the emergence of the modern movement in architecture the solution of mobility in cities was excessively delegated to the genius of transport systems. In turns the rapid technical evolution, the reduction of transport costs (not considering externalities) and the enlargements of the network became in and objective by itself. In this process private cars gained share in the solution of daily journeys despite the inequity in their distribution fostering the ubiquity and extension of travels. In sum, the binomial transport-city arrived to a critical causal relationship, for that reason criticisms raised the necessity to change the paradigm towards the study of

mobility. The design of the city, their public spaces, its structure, allocation of land uses and form (including density) might produce more sustainable solutions to urban mobility, in a more equitable way from the social perspective and the right of citizens to access to the city. Transport and city becomes, thus, in a dialectical relationship instead of a simple causal one (Miralles, 2002).

In this paper we have investigated whether the polycentric structure of the largest metropolitan cities in Spain is correlated with the commuting distance. The results suggest the inverse relationship between the indicators of policentricity and the distance that working population travels to reach their job place. The more equitable is the distribution of employment across subcentres, and the larger the influence of such subcentres in governing commuting patterns the shortest the travelled distance. Such a conclusion has enormous policy implications since it broadens the possibility to solve the mobility problems of cities using an endogenous solution: the spatial arrangement of the city.

Not surprisingly, the results suggest that commuting distances are shorter in centres. The regression models built to explain commuting after controlling for the spatial distribution of employment and population, indicate that excess commuting is alleviated in municipalities where both the job offer and housing is diversified. Thus those zones where job skills and housing preferences match are precisely where commuting is reduced. This conclusion is especially valid in mature subcentres that are not excessively specialised in manufacturing employment.

From a cross sectional perspective our findings support the idea that polycentrism increases the efficiency of urbanisation in commuting terms. Nonetheless, such benefits are reinforced if the spatial structure is accompanied by a diversification of land uses and namely typologies both of housing and economic premises. Such diversity allows workers to find, in the same place, job opportunities according to their skills and housing according to their income level and residential preferences.

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